Comparison of Severn Sound fish assemblages in Hog Bay and Penetang Bay, 1990 and 2002, using two indices of productive capacity.

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ABSTRACT

Brousseau, C.M., Randall, R.G., and Clark, M.G. 2004. Comparison of Severn Sound fish assemblages in Hog Bay and Penetang Bay, 1990 to 2002, using two indices of productive capacity.

In this study, an Index of Biotic Integrity (IBI) developed for Great Lakes littoral habitat and a Habitat Productivity Index (HPI), were used to assess the status of fish assemblages in Hog Bay (1990, 1995, and 2002) and Penetang Bay (1990, 2002). Average annual IBI scores did not change significantly among years in either bay. However, the IBI score for Penetang Bay was higher in 2002 than in 1990 changing the overall rating from fair (>40-60) to good (>60-80). Hog Bay maintained a good rating in all years. At Hog Bay, total species richness and the percentage of piscivores was high in both years but total fish numbers was significantly lower in 2002 than in 1990 because of a significant decline in the catch of pumpkinseed sunfish. In Penetang Bay, the percent piscivores was significantly higher in 2002 (34%) than in 1990 (12%) due to high catches of largemouth bass. Average annual HPI scores were lower for both bays in 2002 than in 1990, but were significant only for Penetang Bay. Total biomass (kg) was significantly lower in 2002 than in 1990 in Penetang Bay due to a reduction in catches of yellow perch, white sucker, and common carp biomass. The percent composition of fish species by biomass and density varied among years in both bays. Non-native and invading fish species comprised only a small percentage of fish biomass and density in the two bays for all sampling years. Generally the IBI and HPI indices indicated diverse and productive fish communities consistent with the fish community objectives described in the Severn Sound Remedial Action Plan.

RÉSUMÉ

C.M., Brousseau, R.G., Randall, et M.G. Clark. 2004. Comparaison dans Severn Sound des assemblages de poisson dans les baie Hog et Penetang, 1990 et 2002, en utilisant deux indices de capacité de production.

Dans cette étude, un indice d'intégrité biotique (IIB), élaboré pour les habitats du littoral des Grands Lacs, et un indice de productivité de l'habitat (IPH) ont été utilisés pour évaluer les assemblages de poissons qui fréquentaient les baies Hog (1990, 1995 et 2002) et Penetang (1990 et 2002). Les cotes IIB annuelles moyennes dans chacune des baies n'ont pas varié beaucoup entre les années d'échantillonnage. Cependant, la cote IIB dans la baie Penetang était plus élevée en 2002 qu'en 1990, ce qui a fait passer la cote globale de passable (>40-60) à bonne (>60-80). La cote globale IIB dans la baie Hog était bonne à chaque année d'échantillonnage. Dans cette même baie, la diversité des espèces et la proportion de piscivores étaient élevées à chaque année d'échantillonnage, mais le nombre total de poissons était beaucoup plus bas en 2002 qu'en 1990 en raison de la forte baisse du stock de crapet-soleil. Dans la baie Penetang, la proportion de piscivores était considérablement plus élevée en 2002 (34 %) qu'en 1990 (12 %) en raison des fortes prises d'achigan à grande bouche. Les cotes IPH annuelles moyennes étaient plus basses en 2002 qu'en 1990 dans les deux baies, mais seules celles dans la baie Penetang l'étaient de façon importante. Dans la baie Penetang, la biomasse totale (kg) était beaucoup plus basse en 2002 qu'en 1990 en raison de la baisse de la biomasse des perchaudes, des meuniers noirs et des carpes. La proportion de chaque espèce de poissons, en termes de biomasse et de densité, a varié entre les années dans les deux baies. À chaque année d'échantillonnage, les espèces de poissons exotiques et envahissantes ne constituaient qu'une petite partie de la biomasse et de la densité des poissons dans les deux baies. De manière générale, l'IIB et l'IPH ont révélé des communautés de poissons diversifiées et productives qui concordaient avec les objectifs en matière de communautés de poissons décrits dans le Plan d'assainissement du bras Severn.

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INTRODUCTION

Severn Sound, located in the southeastern corner of Georgian Bay, consists of a series of bays adjacent to sedimentary landforms opening into the Sound. Hog Bay and Penetang Bay are two narrow bays located on the southern shore of Severn Sound. Severn Sound is a popular tourist destination with a shoreline highly developed with numerous cottages, marinas and resorts. Severn Sound is also a popular centre for recreational and sport fishing (Severn Sound Remedial Action Plan 1989). The Sound ranges from 2 to 4 metres deep in the eastern end to 43 metres deep where the Sound meets Georgian Bay. Poor land use practices have historically degraded the water quality of the Sound and contributed to eutrophication (e.g., farm and sewage run-off) and alteration and degradation of shorelines and wetlands. Approximately 900 agricultural operations are located across the watershed (Sherman 2002). Industry has also played a role in the degradation of the Sound; logging stripped the land, and factories have leached metals (lead and zinc) into the waterways (Sherman 2002). In addition, the sawmill industry (140 years) in the area left much of Penetang Bay with a thick carpet of sawdust, wood slabs and logs (Severn Sound RAP 2001).

The International Joint Commission (IJC) identified Severn Sound as one of 43 Areas of Concern (AOC) in the Great Lakes. In 1987, the IJC informed the Canadian government that Severn Sound met the requirements under the Great Lakes Water Quality Agreement Protocol (GLWQA, 1987) to be designated as an AOC (Minns et al. 1994). Any area in the Great Lakes that had one or more of 14 beneficial uses of the Great Lakes deemed impaired was designated as an AOC. Out of the 14 beneficial uses, five are directly related to fish: restrictions on consumption, tainting, degradation of populations, tumours/deformities, and loss of habitat (Minns et al. 1994). Severn Sound had 8 beneficial uses impaired of which 3 were directly related to fish: restrictions on fish and wildlife consumption (contaminant levels in large fish of some species), degradation of fish and wildlife populations (decline in sport fish populations), and degradation of fish and wildlife habitat (degraded water quality and eutrophication in Penetang Bay). In June 1991, the Stage 1 Remedial Action Plan (RAP) describing environmental conditions and problem definition (Annex 2 of the GLWQA), was approved by the IJC (Sherman 2002).

Minns et al. (1994) developed an Index of Biotic Integrity (IBI) for the lower Great Lakes (and Georgian Bay) to use as a quantitative index of ecosystem health based on

a large fish assemblage dataset collected by a research group (1988-1990) at the Great Lakes Laboratory for Fisheries and Aquatic Sciences (GLLFAS). The IBI was developed to meet the requirements under the RAPs to develop an ecosystem approach in the assessment and monitoring of the beneficial uses (Minns et al. 1994). Four classes of factors that determine the condition of Great Lakes littoral fish assemblages were incorporated into the IBI: non-native species, water quality, physical habitat, and piscivore abundance (Minns et al. 1994). Fisheries and Oceans Canada sampled 85, 100 m transects within Severn Sound during 1990, 1992, and 1995. The Great Lakes IBI was calculated for 3 areas within Severn Sound (Penetang Bay, Hog Bay, and Matchedash Bay) as well as other AOC in the Great Lakes (e.g., Hamilton Harbour and Bay of Quinte) (Minns et al. 1994; Smokorowski et al. 1998). In 2002, Fisheries and Oceans revisited and sampled two areas within Severn Sound, Hog Bay (7 transects) and Penetang Bay (14 transects).

In addition to the IBI score, a Habitat Productivity Index (HPI) was developed as a measure of habitat productive capacity for fish assemblages (Randall and Minns 2002). HPI was related to fish biomass but it also accounted for the size structure of the fish community and was used an index of fish production. The HPI is calculated as the product of fish biomass and the production to biomass ratio (P/B) summed for all species captured at a transect. Used together, HPI and IBI provided indices of the production and diversity components of habitat productive capacity, respectively (Randall and Minns 2002).

As required in the Stage 2 RAP report (detailed RAP, Annex 2, GLWQA), habitat data (i.e. shoreline and aquatic) were collected in Penetang Bay (1989) and Hog Bay (1991, 1992) to provide the Severn Sound RAP with a Geographical Information System (GIS) database of littoral habitats. Littoral habitat data was used to create a habitat classification model (Minns et al. 1999) and areas within the sound were given a classification of high, medium, or low quality according to impairment. At the time of the surveys, Penetang Bay had very few areas classified as high quality while the majority of the Hog Bay shoreline was classified as high quality. In September 2001, the IJC informed the Canadian government that the Stage 2 RAP requirements had been met (Sherman 2002).

In 2002, the Stage 3 report (status of restoration and delisting objectives) was submitted to the Canadian Provincial and Federal governments for review prior to being submitted to the IJC to be de-listed as an AOC (Sherman 2002). Out of the 8 impaired

beneficial uses in Severn Sound, 6 have been completely restored, one has been restored with ongoing targets (degradation of fish and wildlife habitat) and one remains impaired (Sherman 2002). The beneficial use that remains impaired is the degradation of fish and wildlife habitat (objectives 2 and 3). Objective 2 pertains to the restoration of a balanced, self-sustaining fish community with 20 to 30 % of top predators and Objective 3 pertains to the maintenance of a natural diverse fish community that discourages the introduction of non-native species. The impaired beneficial use will be labeled as restored, with the exception of Objectives 2 and 3, provided that responsible agencies commit to a long-term fish monitoring program in Severn Sound to asses the fish community and manage the fishery based on monitoring results (Sherman 2002). Severn Sound was officially de-listed as an AOC in 2002.

The objectives of this study were to compare the data collected in two areas of Severn Sound from different time periods to provide fisheries information for the Stage 3 report (RAP). For each transect sample collected during 2002, an Index of Biotic Integrity (Minns et al. 1994) and a Habitat Productivity Index (Randall and Minns 2002) were calculated and compared to previous years. Together, the IBI and HPI was used to evaluate the diversity and biomass components of productive capacity, respectively. Fish catches of individual species were also evaluated to explain changes or patterns in IBI and HPI metrics. Finally, fish biomass and species composition in areas with sparse and abundant macrophytes were compared in Penetang Bay. Results will be useful for guiding future monitoring at Severn Sound to determine the status of the near shore fish populations in this productive area of Georgian Bay.

METHODS

Study area, habitat, and survey design

Hog Bay

Hog Bay is a small bay located on the southern shore of Georgian Bay (44° 45'N, 79° 47'W). Hog Bay is located between two villages of approximately 2000 residents each; Port McNicoll to the west and Victoria Harbour to the east. Very little of the original Hog Bay shoreline remains unaltered, although years of inactivity in the area have allowed portions of the shoreline to slowly naturalize (Leslie and Timmins, 1995). A large basin was dredged parallel to Hog Bay to accommodate the ships for the grain industry. This dredged basin does not support fish habitat, as it is lined with vertical steel sheeting and concrete docks. There are no residences found on the western side of the

bay, but much of the eastern shoreline has been developed with cottages and permanent residences (Leslie and Timmins, 1995). Hog Bay remains relatively undeveloped compared to other areas in the sound (Minns et al. 1999).

The widest and narrowest sections of the bay are approximately 1.5 km and 0.3 km across respectively, and the length is about 2.0 km. The bay is shallow, reaching just over 2.0 m in depth in many places. The shoreline measures 12.5 km. Macrophyte density was high in the lower basin of the bay. Moderate to heavy vegetation and fine substrates characterized the littoral zone in Hog Bay. Macrophyte density and substrate composition did not change among sampling years (1990, 1995, and 2002). In each year, a total of 14 samples (2 visits x 7 transects) were collected (Table 2, Figure 1).

Penetang Bay

Penetang Bay is a narrow bay located on the southern shore of Severn Sound positioned at 44° 47'N; 79° 56'W. Shoreline development and alterations have resulted in the impairment or loss of 68% of the Bay's historic wetlands (Severn Sound RAP, 1991). Marina expansions have resulted in a continued loss of littoral areas. Many fish species that use wetlands for spawning and nursery habitat (e.g., northern pike and muskellunge) have been affected. Because the majority of shoreline areas in Penetang Bay have been developed (e.g., marinas, residences), there are fewer habitat opportunities for littoral wildlife. A large portion of the shoreline remaining in the bay shows potential for restoration activities (Minns et al. 1999).

Penetang Bay is a semi-confined body of water, protected in a valley from the effects of the prevailing west winds. The bay consists of an inner and an outer harbour. The outer harbour is deeper and forms part of the main body of Severn Sound, while the inner harbour is shallow and sheltered. The club-shaped inner bay is about 5.0 km long, 0.5 to 1.3 km wide, 4.7 m deep, and has a shoreline length of approximately 14.0 km. The substrate in the southern basin consists of fine substrates (e.g., alluvium and detritus), wood chips, bark, and waterlogged lumber. The bottom of the outer harbour consists of silt, clay, sand and gravel. The eastern side of the harbour has been almost completely altered due to industrial, residential and recreational interests (Leslie and Timmins, 1997). Two habitat types were surveyed in the littoral habitats of Penetang Bay: (1) dense: fine substrates with heavy to moderate macrophyte cover and (2) sparse: fine substrates with sparse macrophyte cover. In both years a total of 28

samples was collected (Table 2). In the dense areas, a total of 22 samples was taken in 1990 (2 visits x 11 transects) and 20 samples in 2002 (2 visits x 10 transects). At the sparse sites, 6 samples were taken in 1990 (2 visits x 3 transects) and 8 samples in 2002 (2 visits x 4 transects).

Sampling Techniques

Habitat data at transects were collected before sunset. Prior to surveys, floats were placed at 1.5m depth to visually mark the start and end of the 100 m transects identified by shore markers and GPS positions. To characterize the physical habitat, measures of dissolved oxygen (± 0.3 mg/L), conductivity (± 0.5% *u*S/cm), water temperature (± 0.1°C) and secchi depth (cm) were taken at the middle of each transect and at a point on the 5.0 m depth contour offshore and perpendicular to transects. Substrate was sampled at each transect marker either visually or, for finer substrates, with a long -handled scoop. The substrate was visually and texturally classified as: silt (0.0039 mm to 0.0625 mm), sand (0.0625 mm to 2 mm), gravel (2 mm to 16 mm), pebble (16 mm to 64 mm), cobble (64 mm to 256 mm) or boulder (>256 mm). Other substrate classes included flat bedrock, organic debris, woody debris and zebra mussels. Dominant (>50 %), sub-dominate (10 to 50 %) and trace (<10 %) components of substrate were recorded. Macrophyte abundance at transects was determined visually and assigned to one of four categories: none (0 % bottom cover), sparse (1 to 19 %), moderate (20 to 70 %) or dense (>70 %). Dominant macrophytes were identified to genus (Newmaster et al. 1997).

The electrofishing surveys were conducted at 1.5 metre water depth, along transects that were 100 metres in length. Transect sites were marked with buoys and shore markers, and were approximately the same locations in all years. The surveys were initiated in the evening and continued after dark. All captured fish were identified to species by the field crew, individually measured (length in mm, weight in grams) and then returned to the water. For the 2002 survey, photos were taken of unknown species such as young-of-the-year esocids (e.g., muskellunge) and redhorse suckers (e.g., silver redhorse) and identification was confirmed by Dr. Nick Mandrak (GLLFAS, Fisheries and Oceans Canada). In addition to the individual fish records, total fish numbers, biomass and species richness were recorded for each transect. All fish and habitat data were recorded on field data sheets, and later entered into a computer database.

For fish samples from each transect, an IBI score and an adjusted IBI* score (exclusion of offshore species) were calculated using the software described by Stoneman (1998). IBI scores were calculated using 12 separate assemblage metrics that were based on the diversity and trophic characteristics of the fish community. Positive metrics included indicators of species richness (native, centrarchid, intolerant and native cyprinid), trophic composition (percent piscivore and specialist biomass), and abundance (number and biomass of native fish). Negative metrics included non-native species richness, percent generalist biomass, and percent number and percent biomass of non-native fish species. IBI metrics were standardized and summed to produce an IBI score that ranged between 0 and 100.

In addition, for each transect, an HPI and adjusted HPI* (exclusion of offshore species) were also calculated. First, average biomass (kg/ha) was calculated for each species by transect. A production index for each species was then calculated as the product of average biomass and a species P/B ratio determined by $P/B= 2.64W^{-0.35}$ (for more details see Randall and Minns 2002). Weight (W) was the average weight for each species caught at a transect. A final HPI (kg/ha/y) for each transect was calculated as the sum of the production indices of all species captured at the transect.

Statistical analysis

For comparing average IBI and HPI indices between years, analysis of variance (ANOVA) was used on square-root transformed IBI and IBI* data and log (x+1)-transformed HPI, HPI*, and catch (biomass and numbers) data. The non-parametric Kruskal-Wallis (KW) and Mann-Whitney U tests were used on the individual IBI metric scores and individual species catch (i.e. biomass and numbers) data.

Transects were grouped by area (Hog Bay and Penetang Bay) and habitat characteristics (sparse or dense macrophytes). Transects with sparse or no macrophytes were characterized as a 'sparse' habitat. Transects with either moderate or dense vegetation were grouped and characterized as a 'dense' habitat. In Hog Bay, all transects were characterized by dense vegetation. In Penetang Bay, transects were grouped into sparse and dense cover habitats and comparisons were made of the fish catches between habitats. Data were analyzed for each bay separately, using one factor (year) ANOVA in Hog Bay, and two-factor ANOVA (year, habitat) in Penetang Bay. All statistical results were considered significant at $\alpha < 0.05$.

RESULTS

Hog Bay

Habitat: Cover, substrate, and exposure conditions were similar at all Hog Bay transects. In Hog Bay, transects were classified as moderately vegetated (5, 8, and 10) or densely vegetated (7, 12, 13, and 14). The macrophyte densities at all sites did not change by year and were not affected by position in the bay (Figure 1). There were three dominant macrophytes found at all sites: water milfoil (*Myrophyllum* sp.), water celery (*Vallisneria* sp.) and Canada waterweed (*Elodea canadensis*). Several species of pondweed (*Potomageton* sp.) and *Heteranthera* sp. were found at transects (10, 12, 13, and 14) along the less-developed western shoreline but not at transects along the eastern portion of the bay (5, 7, or 8). All transects were characterized by fine substrate (i.e. silt and sand). Average water temperature varied among years and was the highest in 2002: 1990 (24.2°C, range: 22.0-25.0°C), 1995 (21.7°C, range: 12.2-26.2°C), and 2002 (26.4°C, range: 23.4-30.0°C). In all years, the water clarity at 1.5 m-depth was clear to the bottom. Average water conductivity was slightly higher in 2002 (221.6 *u*S/cm) than in 1995 (178.2 *u*S/cm) and no values were reported for 1990. Averaged dissolved oxygen in 2002 was 8.4 mg/L.

Index of Biotic Integrity: Total species richness (Table 1) in Hog Bay has not changed significantly over time but it did increase between 1990 and 2002 from 5.8 (range 4-9) to 6.9 (5-10) species per transect, respectively (Figure 4). Both average total biomass (kg) and total numbers per transect decreased between 1990 and 2002 but only total numbers decreased significantly (ANOVA, $F_{2,38}$=4.249, P=0.0220) (Figure 3). Average biomass per transect was highest in 1995 at 6.0 kg (0.1-34.8 kg) and lowest in 2002 at 3.9 kg (0.4-12.6 kg). Average number of fish per transect was highest in 1990 at 62.4 individuals (17-160) and lowest in 2002 at 30.1 (16-55).

Results of the overall IBI calculation indicated that the value for the overall fish community in the littoral zone decreased slightly but not significantly in 2002 compared to 1990 (ANOVA, $F_{2, 38}$= 0.164, P=0.849) (Figure 13). An IBI score of 66.0 in 2002 indicated that the fish community in Hog Bay has maintained a good rating (>60-80) (Minns et al. 1994). Similarly, the adjusted IBI* decreased but not significantly to 66.0 in 2002 (ANOVA, $F_{2, 38}$= 0.160, P= 0.880) (Figure 13). There was little difference between

the IBI and IBI* because offshore species contributed less than 1 % by number and biomass to the regular IBI.

None of the individual richness metrics (Table 3) showed significant change among years (KW, P>0.05). Native species richness increased from 5.5 (1990) to 6.4 (1995) and then decreased slightly to 6.3 in 2002 (Figure 5). In 2002, 5 native species (longnose gar, muskellunge, blacknose shiner, creek chub, and bluegill sunfish) were captured for the first time by electrofishing in Hog Bay. Although the 5 species were new to the productive capacity database, they were not new to the area (Mandrak and Crossman 1992; Leslie and Timmins 1995). Centrarchid species richness was highest in 1990 (average of 3.1 per transect) and decreased to an average of 2.8 in 2002 (Figure 5). Both turbidity intolerant species richness (0.8) (Figure 6) and native cyprinid species richness (1.2) (Figure 7) were higher per transect in 2002. In 2002, the blacknose shiner, a cyprinid that is intolerant of turbidity, averaged about 4 individuals per transect in Hog Bay. Non-native species richness in 2002 (0.5) remained low at less than one species per transect (Figure 6).

The trophic component of the IBI is made up of three groups (piscivores, generalists, and specialists) expressed in terms of percentage of total biomass (Table 3). None of the trophic components differed significantly between years (KW, P>0.05). The percentage of piscivores by biomass was higher at 37.1 % in 2002 than it was in 1990 (30 %) but less than 39.0 % in 1995 (Figure 7). As noted above, two piscivores, the longnose gar and the muskellunge, were caught for the first time in 2002. The presence of young-of-the-year (YOY) muskellunge (130-200 mm) indicated that natural reproduction of this species was occurring in Hog Bay. The objective for overall predator levels in Severn Sound (20-30 %) was achieved in Hog Bay but the walleye objectives were not. No walleye were caught in Hog Bay in 2002. The average percentage of specialists by biomass was lowest in 2002 at 41.5 % (Figure 8). Generalists comprised 21.4 % of the biomass in 2002 (Figure 8).

The remaining two positive metrics in the IBI calculation are the number and biomass of native fish. The average number of native fish per transect decreased significantly in 2002 from 1990 (KW=7.963, P=0.019). The average number of native fish per transect in Hog Bay dropped from 61.7 (17-160) in 1990 to 38.6 (5-93) in 1995 and 29.1 (15-55) in 2002 (Figure 9). The biomass of native fish decreased between 1990 and 2002 to an average value of 2.6 kg per transect. The percentage of native fish biomass continues to remain high (> 80%) in Hog Bay (Figure 11).

The two final negative metrics included in the IBI calculations are percent non-native fish by number and biomass over time (Figure 10). The percent non-native fish by number was highest in Hog Bay in 1995 (4.0 %) and decreased to 2.8 % in 2002. The percent non-native fish by biomass remained constant at 15 % in the three sampling years (1990, 1995, and 2002).

Habitat Productivity Index: The results of the calculation of the HPI (ANOVA $F_{2,38}$ = 2.669, P= 0.082) and HPI* (ANOVA $F_{2,38}$ = 2.606, P= 0.087) indicated that these values decreased but not significantly among years (Figure 14). These results were consistent with the IBI in that no significant change in the fish assemblage occurred between years (Figure 13). No change in the HPI and HPI* values were consistent with a non-significant decrease in total biomass in Hog Bay between 1990 and 2002 (Figure 3). Between 1990 and 2002, the mean individual weight of fish increased from 90.0 g to 224.0 g then decreased to 174.0 g in 2002 (Figure 4).

Comparison of catches of individual species: The percent biomass by species varied among years (Table 4, Figure 15). Two species, common carp and largemouth bass, were major contributors (>10%) to total biomass in all three years. In 1990 and 1995, pumpkinseed sunfish also made up more than 10% of the biomass but not in 2002 (4%). Pumpkinseed biomass decreased significantly (KW=13.941, P=0.001) among years: 1990 (1.2 kg), 1995 (0.7 kg) and 2002 (0.2 kg) (Table 4). Yellow perch comprised 21 % of total biomass in 1990 but less than 10 % in the other two years (Figure 15). There was a significant decrease in yellow perch biomass among years (KW=20.658, P<0.001) as average biomass per transect decreased from 1.1 kg in 1990 to 0.2 kg in 2002 (Table 4). In 2002, bowfin made up 21% of the total biomass, an increase from 8 % in 1990 and 4 % in 1995 (Table 4, Figure 15).

The mean catch by numbers of individual fish species is listed in Table 5. Three species (pumpkinseed, largemouth bass, and yellow perch) comprised a large percentage of the total number of fish in Hog Bay in all three years (Figure 15). In 1990 and 1995, largemouth bass made up 7 % and 9 %, respectively of total numbers but increased to comprise 22 % of total numbers in 2002 (Figure 15). The blackchin shiner comprised 8.5 % of total numbers in 1995 but only 3 % in 1990 and 1995. Cyprinids comprised only 1.4 % of the catch in 1990 but increased to 4.3 % in 1995 and 6.1 % in 2002 (Figure 15, Table 4). Common shiner numbers changed significantly among years

(KW=6.090, P=0.048) and the number of creek chub increased significantly (KW=9.296, P=0.010) in 2002 (Table 5).

The number of pumpkinseed sunfish in Hog Bay was significantly lower in 2002 than in 1990 (KW=10.457, P=0.005). Despite the significant declines in percent pumpkinseeds in 2002 (19 % by number) compared to 46 % (1990) and 40 % (1995), this species was still a major contributor to the total numbers of fish in Hog Bay (Figure 15).

Penetang Bay

Habitat: Transects in Penetang Bay were characterized by either sparse or dense vegetation with fine substrates. In 1990, 3 transects were characterized by sparse vegetation (16, 18, and 20) and 11 transects by dense vegetation (Figure 2). In 2002, 3 transects were characterized by sparse vegetation at both sampling visits (15, 16, and 18) while transects 14 and 26 were sparsely vegetated during the July visit but densely vegetated during the August visit. Most of the sparsely vegetated transects (14-18) were found in the more wind-exposed outer bay and transect 20 was located on the exposed side of Magazine Island (Figure 2). Water milfoil (*Myrophyllum* sp.), water celery (*Vallisneria* sp.) and Canada waterweed (*Elodea canadensis*) were the predominant macrophytes found in Penetang Bay but they were not found at all transects. A few or none of the dominant macrophytes were found at transects 16, 18, 21, and 23 (Figure 2). Low macrophyte diversity at these transects may be correlated with moderate wind exposure/fetch (16 and 18) and substrates that were comprised predominantly of sand (16, 18, 21, and 23).

Average water temperature was 22.6°C (21.0-25.0°C) in 1990 and 25.0°C (23.5-27.3°C) in 2002. Secchi depth at 1.5 m was clear to the bottom in both years. In 2002, average conductivity and dissolved oxygen were 211.2 *u*S/cm and 8.7 mg/L, respectively. Conductivity and dissolved oxygen data were not collected in 1990.

Index of Biotic Integrity: Results of the IBI calculation indicated that the value for the overall fish community in the littoral zone was higher in 2002 than in 1990 but not significantly (ANOVA, $F_{1, 54}$= 0.316, P=0.5769) (Figure 13). The IBI score increased from 60.0 (1990) to 64.8 (2002) indicating that the fish community in Penetang Bay has increased from a fair (<40-60) to a good rating (>60-80) (Minns et al. 1994). Similarly,

the adjusted IBI* increased from 58.0 (1990) to an average score of to 63.0 (2002) (Figure 13). There was little difference between the IBI and IBI* because offshore species contributed less than 5 % by number and biomass.

Average total species richness was similar in 2002 (5.7) and 1990 (5.5) (Figure 4). In 2002, 7 species were caught in Penetang Bay that had not been captured before during electrofishing surveys. Of the 7 new species, 6 were native (longnose gar, central mudminnow, blacknose shiner, creek chub, stonecat and banded killifish) and one was non-native (white perch). It was the first time a stonecat has been reported in this area (N. Mandrak, pers. comm.; Mandrak and Crossman 1992). The other species have been reported in Penetang Bay by other researchers (Mandrak and Crossman 1992; Leslie and Timmins 1997). A decrease in average total biomass (kg) and total numbers between 1990 and 2002 was only significant for biomass (ANOVA, $F_{1,54}$= 15.869, P<0.001) (Figure 3). Average biomass per transect decreased from 4.9 kg (0-17.7 kg) in 1990 to 1.6 kg (0-6.4 kg) in 2002. Average numbers decreased slightly per transect from 38.7 fish (0-161) in 1990 to 32.3 fish (0-100) in 2002. Mean weight of individual fish in Penetang Bay decreased significantly (MWU= 634.5, P<0.001) between 1990 and 2002 (Figure 4).

Native species richness (longnose gar, banded killifish, and stonecat) remained constant at 5.0 species per transect in both years (Figure 5). Centrarchid (sunfish and bass), turbidity intolerant (blacknose shiner), and cyprinid (creek chub) species richness all increased on average between 1990 and 2002 (Figures 5, 6, and 7). Non-native (white perch) species richness remained constant at 0.4 fish per transect in both years (Figure 6). Average turbidity intolerant (KW=254.5, P=0.015) species richness and cyprinid (KW=287.0, P=0.070) species richness were both significantly higher per transect in 2002.

Percent piscivores increased significantly between years (KW=197.0, P=0.001) from 12.2 % (1990) to 34.4 % (2002) (Figure 7). An increase in percent piscivores was consistent with Objective 2 of the Severn Sound RAP to restore piscivore levels from 20 to 30 % of the total catch. In 2002, the majority of piscivore biomass was comprised of longnose gar, bowfin, and largemouth bass. Largemouth bass have increased significantly in biomass (MWU=192.0, P=0.001) and numbers (MWU= 82.0, P<0.001) between the 1990 and 2002 surveys in Penetang Bay. No walleye (*Stizostedium vitreum vitreum*) were caught in 2002 therefore; the Severn Sound RAP objective of walleye comprising 10 % of the piscivore catch was not achieved. Both percent

generalists and percent specialists were lower in 2002 (Figure 8) than in 1990 but these differences were not significant (P>0.05).

The biomass of native fish decreased significantly from 4.1 kg in 1990 to 1.5 kg in 2002 (KW=602.0, P= 0.001; Fig. 9). Despite the significant decrease in native fish biomass, the percentage of native fish contributing to total biomass (kg) remained high at about 90 % in 2002 (Figure 11). The number and biomass of non-native fish decreased between 1990 and 2002 to below 5 % for each metric (Figure 10). The percentage of offshore fish contributing to total fish numbers and biomass decreased in 2002 (Figure 12). The average percentage of offshore fish by number was only 4.4 per transect and by biomass was only 1.3% per transect.

Habitat Productivity Index: Results from the calculation of the HPI indicated a significant decrease (ANOVA, $F_{1,54}$ =5.722, P= 0.020) in the index between the 1990 and 2002 surveys (Figure 14). Similarly, HPI* decreased significantly between years (ANOVA, $F_{1,54}$ =5.350, P= 0.025). A decrease in HPI values was consistent with a significant decrease in total biomass between 1990 and 2002 in Penetang Bay (Figure 3). Results of the HPI analysis were different from the IBI analysis which, as indicated above, showed a similar fish community score between years. Therefore, although biomass was lower in 2002, species diversity remained high.

*Comparison of catches of individual species by habitat type: A*verage biomass (kg) varied by habitat type (sparse or dense macrophytes) and year. With average log_biomass as (kg) as the dependent variable, and habitat type and year as the independent variables, results of a two-way ANOVA indicated that the interaction term (ANOVA, habitat*year; $F_{1,52}$ =0.456, P=0.502) was not significant. Average biomass (kg) was significantly higher at densely vegetated transects (high quality) than at sparsely vegetated transects (ANOVA, $F_{1,52}$=7.496, P=0.008) and annual values indicated that biomass was higher at both habitat areas in 1990 than in 2002, although not significantly (ANOVA, $F_{1,52}$ = 3.508, P=0.067). A second ANOVA with average log_numbers as the dependent variable and habitat type and year as the independent variables, indicated that the interaction term was not significant (ANOVA, habitat*year; $F_{1,52}$ =0.306, P=0.583). The numbers of fish caught in Penetang Bay did not vary by year (ANOVA, $F_{1,52}$=0.001, P=0.978) but the average numbers of fish caught were significantly higher (ANOVA, $F_{1,52}$=22.538, P<0.001) at dense transects than sparse transects. The average

number of fish caught at dense transects was 46.0 (1990) and 40.0 (2002) compared to 17.0 (1990) and 13.0 (2002) at sparse transects. Average species richness showed the same trend among habitat type and year as log_numbers. Average species richness at dense transects was significantly higher than species richness at sparse transects (ANOVA, $F_{1,52}$=6.690, P=0.013). Species richness at dense transects was 5.9 (1990) and 6.4 (2002) compared to 4.2 (1990) and 4.1 (2002) in sparse areas.

White sucker was an important species in Penetang Bay. It comprised a large percentage (> 10%) of total biomass in both sparse and dense areas in 1990 and 2002 (Figure 16). At the sparse habitats, white sucker made up 38.5% and 13.2% of total biomass in 1990 and 2002, respectively. White sucker biomass was significantly higher in 1990 than in 2002 (MWU= 540.0, P=0.007). In 1990, quillbacks, smallmouth bass, and yellow perch each contributed greater than 10% to total biomass while alewife (4.9%) and pumpkinseed (6.0%) were also important species in sparsely vegetated areas (Figure 16). With the exception of the white sucker, the major contributors to total biomass in sparsely vegetated areas were different in 2002 than in 1990. Quillback (MWU=462.0k, P=0.020) and yellow perch (MWU=701.5, P<0.001) biomass have declined significantly since 1990 (Table 4). In 2002, silver redhorse, pumpkinseed sunfish, and largemouth bass were the major contributors (>10%) to total biomass in sparsely vegetated habitats (Figure 16). Largemouth bass biomass increased significantly (MWU=192.0, P=0.001) in 2002 (Table 4). White perch, an offshore, non-native species, made up 6.6% of biomass at sparse sites in 2002.

At the densely vegetated sites, five species contributed significantly to total biomass in both years but the magnitude varied between years (Figure 16). In 1990, white sucker (25.6%), common carp (22.9%) and yellow perch (22.6%) were the major contributors to total biomass. Other species that made significant contributions but less than 10% in 1990 included pumpkinseed (8.5%), largemouth bass (4.7%), and bowfin (3.4%). In contrast, species contributing to greater than 10% of total biomass in 2002 were pumpkinseed (28.5%), largemouth bass (24.8%) and bowfin (15.5%). Species that contributed greater than 10% in 1990 contributed less than 10% in 2002: white sucker (7.2%), common carp (8.7%), and yellow perch (3.1%). Average biomass of yellow perch decreased from 1.37 kg per transect in 1990 to 0.06 kg per transect in 2002 (Table 4). Largemouth bass biomass increased from 0.29 kg per transect in 1990 to 0.50 kg per transect in 2002 (Table 4).

In the sparsely vegetated areas, species making up greater than 10% of total numbers was different in 1990 than in 2002 (Figure 17). In 1990, alewife, smallmouth bass, and yellow perch each contributed significantly (>10%) to total numbers. Other lesser contributors (<10%) included white sucker, pumpkinseed, and rock bass (Figure 17). In 2002, only two species (pumpkinseed and largemouth bass) made up greater than 10% of total numbers while other important contributors (<10%) included bluntnose minnow, alewife (5.0%), and white perch (5.0%). Between the two years, average smallmouth bass numbers decreased from 2.7 fish per transect (1990) to 0.3 fish (2002) and average yellow perch numbers decreased from 5.8 fish (1990) to 0.3 fish (Table 5). Average largemouth bass numbers increased from no fish in 1990 to 4.6 fish per transect in 2002 (Table 5).

In the dense cover areas, pumpkinseed sunfish made up 22% of total numbers in 1990 and 51% in 2002 (Figure 17). Average number of pumpkinseeds per transect doubled between the two sampling years from 10.0 fish (1990) to 20.4 fish (2002) (Table 4, MWU=256.0, P=0.025). Yellow perch made up 49.4% of total numbers at dense cover transects in 1990 but was significantly lower, 2.1 % (MWU=714.0, P<0.001) in 2002. Like the sparse cover habitats, the average number of yellow perch per transect in the densely vegetated areas declined from 22.5 fish (1990) to 0.9 fish (2002) (Table 5). In contrast, the proportion of largemouth bass was significantly higher (24.4 %, MWU=42.0, P<0.001) in 2002 than in 1990 (2.9%, Figure 26). The average number of largemouth bass per transect increased from 1.3 in 1990 to 9.8 in 2002 (Table 5). In 1990, the secondary contributors (<10%) to total numbers (dense) included alewife, white sucker, and rock bass. In 2002, cyprinids were the major secondary contributors totaling 13% of total numbers compared to only 3.0% in 1990 (Figure 17). The catch of spottail shiners in numbers was significantly higher in 2002 (MWU=278.0, P=0.005) than in 1990 (Table 5).

DISCUSSION

Results from the 2002 surveys in Hog and Penetang Bays indicated that the fish assemblages in these areas are in good standing according to the Great Lakes Index of Biotic Integrity (IBI; Minns et al. 1994) and the Habitat Productivity Index (HPI) (Randall and Minns 2002). Based on the catch data from 1990, three bays in Severn Sound were ranked using the IBI from the most degraded to the least degraded: Penetang Bay, Hog Bay, and Matchedash Bay (Minns et al. 1994). In 2002, the average IBI scores from Penetang (65) and Hog (66) bays were not different from each other or the 1990 score from Matchedash Bay (66) indicating, that conditions for fish in Penetang Bay may have improved somewhat since 1990. By comparison, fish assemblages in both areas of Severn Sound were healthier than in the Hamilton Harbour AOC (Lake Ontario), which was also surveyed in 2002. The average IBI score for transects sampled in Hamilton Harbour in 2002 was 37.0 (poor) compared to 65.0 in Penetang Bay and 66.0 in Hog Bay (Brousseau and Randall 2003). Electrofishing survey data in 2002 confirmed that the fish communities in Severn Sound have remained relatively diverse and productive.

Hog Bay

At the survey transect locations, habitat conditions in Hog Bay did not change between 1990 and 2002. Due to limited shoreline development between 1990 and 2002 (Sherman 2002), high quality habitat was maintained at all transects in Hog Bay. According to the habitat classification system by Minns et al. (1999), transects surveyed in Hog Bay fall into the category of high quality habitat (i.e. sand/silt substrates with dense macrophytes). Macrophyte species richness was not as high along the more developed eastern shoreline but macrophyte density has not changed since the last habitat survey (1991-1992) (Minns et al. 1999).

The IBI and adjusted IBI* scores decreased slightly but not significantly among years (1990, 1995, and 2002) and maintained good ratings (average IBI scores, 60-80). As expected, there were no significant changes in average total species richness. Species found in Hog Bay use shallow water, fine substrates, and aquatic vegetation as cover (Randall et al. 1998). All of the fish captured in our survey, except muskellunge, were previously caught in larval fish surveys (Leslie and Timmins 1995) of Hog Bay indicating that these species spawn and reproduce in this bay. There were no significant changes in any of the positive richness metrics and non-native species richness

remained low at less than 0.5 species per transect. Both centrarchids and native cyprinids were well-represented in Hog Bay indicating a mature, stable ecosystem of high habitat diversity (Minns et al. 1994). Low non-native species richness was in compliance with Objective 3 of the fish community beneficial use to maintain a natural fish community that discourages the introduction of non-native species (Sherman 2002) The HPI and HPI* were lower in 2002 than in 1990 but not significantly as expected by a non-significant decrease in average biomass between years. None of the trophic components of biomass were different among the survey years. The percentage of piscivores found in the bay continued to surpass objectives of the Severn Sound RAP for top predators (20-30%) but it did not include a walleye component (10%) and therefore, this objective remained impaired. Two new predators were caught in the bay, longnose gar and YOY muskellunge. The presence of YOY muskellunge confirmed that muskellunge are reproducing naturally and that Hog Bay provided suitable spawning and nursery habitat for this species. The presence of littoral piscivores was an indicator of high quality habitat in the littoral zone (Minns et al. 1994). Percent specialists remained high (42%) despite a significant decline in pumpkinseed sunfish and generalists comprised a lesser percentage of total biomass (21%).

The most obvious change in the 2002 fish assemblage was a significant decline in the catch of certain species. The numbers of fish per transect in 2002 were half of what they were in 1990 and 1995. A decrease in numbers was directly related to a significant decrease in pumpkinseed sunfish. In 2002, pumpkinseed made up 19% of the total numbers of fish in Hog Bay which was less than half the numbers in 1990 and 1995. There were also significant decreases in both pumpkinseed and yellow perch biomass. A decline in these two species could be related to numerous factors including predator-prey interactions (e.g., piscivorous birds and fish), exploitation, natural cycles in fish populations, and variability in conditions at the time of survey (i.e., higher than average water temperatures in 2002). According to these recent survey results, habitat degradation and competition with non-native and invading species were unlikely factors contributing to species declines. The reduced catch of these species did not affect the overall IBI scores, as noted above. Randall and Minns (2002) showed that although IBI and HPI were positively correlated, there was much variability in the relationship between these two indices, and HPI (biomass) can vary significantly for any level of IBI.

The percentage of largemouth bass numbers was significantly lower (less than 10 %) in the earlier years than in 2002 (22%). In 2002, relatively high bowfin biomass

and the capture of two new predators (longnose gar and muskellunge) indicated that top predators are apparently doing well in Hog Bay. Both pumpkinseed sunfish and yellow perch are common prey of piscivores in Hog Bay (Scott and Crossman 1973). According to summer creel surveys conducted in Severn Sound (1975-2001), pumpkinseed and yellow perch have been exploited in the past (Sherman 2002). Also, yellow perch, like many populations, inherently exhibit fluctuations in abundance and production from one year to the next.

Penetang Bay

There was little change in habitat conditions at 14 transects surveyed in 1990 and 2002. In each year, 3 transects were classified as medium suitability habitat (i.e. dominant sand substrate with sparse vegetation) (Minns et al. 1999). Transects characterized by medium quality habitat varied between the two years, 1990 (16, 18, 20) and 2002 (15, 16, and 18), but were found in both years at exposed areas along Magazine Island (20) or in the outer bay. Eleven transects in each year were classified as high quality habitat. The removal of sawdust, wood-slabs, and logs in October, 1994 led to the restoration of 4 hectares of nearshore habitat by promoting the re-establishment of aquatic macrophyte growth (Environment Canada 2001). Nutrient loadings from point sources (e.g., STP) and non-point sources (e.g., urban and rural run-off) have been reduced and a decrease in suspended algae and an increase in water clarity have been noted (Environment Canada 2001). In addition, a Fish Habitat Management Plan (FHMP) to guide development away from sensitive, nearshore areas has also been put into place.

A slight increase in the IBI score for Penetang Bay indicated that the biotic integrity of the fish assemblage has been maintained or possibly improved. According to Minns et al. (1994), both the IBI and adjusted IBI* have increased enough to change the rating in Penetang Bay from fair (>40-60) to good (>60-80). Average total and native species richness did not change significantly between the 1990 and 2002 survey years, but 7 new species were added to the Penetang Bay electrofishing database. The fish caught in Penetang Bay were species common to cool and warm-waters in the Great Lakes and have been caught before in larval fish surveys of Penetang Bay (Leslie and Timmins 1997). Centrarchid, turbidity intolerant and cyprinid species richness all increased in 2002. Similar to Hog Bay, the presence and richness of centrarchids and cyprinids in Penetang Bay is consistent with diverse habitats and ecosystem stability in

the Great Lakes (Minns et al. 1994). Turbidity intolerant species richness increased significantly (e.g., spottail shiners and blacknose shiners) in Penetang Bay. An increase in turbidity intolerant species abundance suggests that efforts to reduce urban runoff and the removal of sawdust in sediments have been successful. Non-native species richness did not increase between 1990 and 2002 which is consistent with the RAP objective (3) of maintaining a natural fish community that discourages the introduction of non-native species. Non-native numbers and biomass of fish continued to remain low at less than 5 % of the sampled population.

Significantly, the percent of piscivores contributing to total biomass was higher in 2002 than in 1990 in Penetang Bay due to the increase in catches of largemouth bass. The percentage of piscivores rose from only 12.2 % in 1990 to 34.4 % in 2002 which exceeds the objective for top predators (Objective 2) set by the Severn Sound RAP. The significant increase in littoral predators suggests that habitat conditions have improved for species like largemouth bass and bowfin that require high quality habitat (i.e. fine substrates and dense macrophytes). However, like Hog Bay, no walleye were caught in Penetang Bay and therefore, the part of Objective 3 that states that walleye comprise 10 % of piscivores was not achieved. Specialists (i.e. herbivores, planktivores, and insectivores) comprised over 50% of the total biomass while percent generalists remained low at 7.4%.

Overall, total biomass decreased significantly in 2002 to approximately half of what it was in 1990. In 2002, significant declines in several species abundant in the 1990 survey were noted: white sucker, smallmouth bass, and yellow perch. Largemouth bass and spottail shiners were the only species that increased significantly by biomass while spottail shiners, pumpkinseed, and largemouth bass increased significantly by number. The significant reduction in fish biomass contributed to a significant decrease in HPI and HPI* values between years. A decrease in HPI values suggests that fish production in terms of biomass was less in 2002 than in 1990 in Penetang Harbour. Fish density was similar between years. Similar to Hog Bay, the decline in biomass of some species did not affect the overall IBI scores in Penetang Bay.

In the sparsely vegetated habitats, there was a shift in the dominant species of fish between 1990 and 2002. The fish assemblage changed from species more characteristic of cool water and sparse vegetation to common species found in warm, shallow, and heavily-vegetated areas. The contribution of smallmouth bass, yellow perch, and white sucker to total biomass decreased significantly between the 1990 and

2002 surveys and was replaced by largemouth bass and pumpkinseed. Similarly in 2002, a significant decline in the catch in numbers of alewife, smallmouth bass and yellow perch was concurrent with a significant increase in pumpkinseed and largemouth bass. According to Randall et al. (1998), these sparse macrophyte habitats may be spill-over areas that support similar species of fish to nearby densely vegetated areas but at lower densities. There are a number of factors that could be responsible for the changes seen in the fish assemblage in sparsely vegetated areas: natural variability in relative abundance, possible increased macrophyte growth in close proximity to the transects, exploitation, cormorant predation, and variability in conditions at the time of survey. Smallmouth bass and yellow perch have been exploited in Severn Sound (Sherman 2002). For example, the average number or smallmouth bass caught in summer creel surveys between 1975 and 2001 ranged from 1,600 to about 12,000 fish, respectively. Cormorant predation may also be having an effect on Penetang Bay fish populations. Lakes Huron and Ontario support the highest densities of cormorants in the Great Lakes (Weseloh 2003). Lake Huron has unlimited habitat and a good forage base for piscivorous fish and cormorants that feed regularly in Penetang Bay (pers. comm. with Keith Sherman, Severn Sound RAP). Recent studies in Lake Ontario have shown that declines in smallmouth bass abundance have been linked to cormorant predation and climatic variability (Casselman et al. 2002). Other cormorant studies in Lake Ontario have shown that in nearshore areas, these birds prey predominantly on smallmouth bass, yellow perch, and rock bass (Weseloh 2003).

In the densely vegetated areas of Penetang Bay, the major contributors (>10%) to biomass in 1990 contributed less than 10% in 2002. As observed in the sparse cover habitats, significant declines in white sucker and yellow perch biomass were found as well as a significant decrease in common carp biomass (Objective 3). While common carp comprised over 20% of total biomass in 1990 it decreased to about 9% in 2002. In contrast, the numbers of pumpkinseed sunfish in Penetang Bay doubled between 1990 and 2002. Also, a large catch of largemouth bass in 2002 relative to 1990 indicated that the habitat in Penetang Bay is highly suitable for this species. A rise in the numbers of cyprinids contributing to total numbers was also noted in 2002. In contrast, yellow perch catches per transect were lower. Factors such as exploitation coupled with cormorant predation and natural variability in year-class strength may have contributed to declines in yellow perch (2002).

SUMMARY

The IBI and HPI are tools for assessing fish assemblages in littoral areas of the Great Lakes and can be linked to habitat diversity and quality (Randall and Minns 2002). The results of this study indicated that both Hog Bay and Penetang Bay have diverse, natural fish assemblages. Both areas had high IBI scores and although HPI in Penetang Bay was significantly lower than the previous sampling period, the system was still relatively productive. The use of both the IBI and the HPI together indicated a relatively healthy, diverse, and productive fish community in Severn Sound.

During the 2002 sampling period, both similarities and differences were found between the two bays. In both Hog and Penetang bays, there were no significant differences in IBI scores between sampling periods. Species richness metrics are strongly correlated with IBI scores therefore; no change in both positive (i.e. native species richness) and negative (i.e. non-native species richness) richness metrics between years was expected in the two bays. Physical habitat conditions at transect locations varied little between years but water temperatures were on average 2-4°C higher in 2002 in both bays and water clarity in Penetang Bay had increased since 1990. There was an increase in catches of turbidity intolerant species in Penetang Bay, possibly due to an increase in water clarity resulting from the remedial efforts. Higher water temperatures in 2002 at the time of survey may have contributed to the absence of walleye and the decrease in yellow perch in the catch data, but this is speculative. Piscivorous largemouth bass increased significantly in catch (numbers and biomass) in both bays between the 1990 and 2002 sampling periods.

The fish catch varied to a certain degree between Hog Bay and Penetang Bay. In Hog Bay, fish density decreased significantly between years due to a decline in pumpkinseed numbers while fish biomass in Penetang Bay decreased significantly between years as a result of declines in the biomass of several species (yellow perch, white sucker, smallmouth bass, and common carp). In contrast to Hog Bay, pumpkinseed numbers increased significantly between 1990 and 2002 in Penetang Bay. As fish biomass is linked strongly with the HPI score, a significant decrease in the HPI scores between sampling periods (1990 and 2002) was found in Penetang Bay but not Hog Bay.

As mentioned above, significant changes occurred between the sampling periods in Hog Bay (1990, 1995, and 2002) and Penetang Bay (1990 and 2002). In both bays, there was a significant decline in yellow perch biomass between 1990 and 2002 while Penetang Bay experienced a significant decline in overall biomass. In Penetang Bay, a significant increase in littoral predators was also found between the two years as the fish assemblage changed from a species base more characteristic of cool water and sparsely vegetated habitats to those species commonly found in warm, shallow, and heavily vegetated areas.

In the future, nearshore fish communities in Severn Sound should be monitored periodically (every 3 to 5 years as in Hamilton Harbour) using the standardized electrofishing protocol (Valere 1996; Brousseau *et al.* 2004 *in press*) to establish a time series dataset. Also, other areas in Severn Sound should be revisited (e.g., Matchedash Bay, Green Island, and Sturgeon Bay) as well as other areas that haven't been sampled to date (Midland Bay). Studies on the status of the walleye fishery in Severn Sound should continue as this species has been captured by electrofishing in other areas of the Great Lakes (e.g., Bay of Quinte, Lake Ontario). Since the de-listing objectives were established in 1992, several factors have emerged that may be influencing Severn Sound fish populations including fishing pressure (i.e. angling), the introduction of non-native species (e.g., zebra mussel and round goby), increase in the abundance of double-crested cormorant, change in trophic status due to phosphorus control, and a decrease in water levels (Sherman 2002). Periodic sampling will be useful in determining the effects of the variables that affect fish populations including new non-native invaders such as the round goby.

ACKNOWLEDGEMENTS

We thank Ken Minns for his advice and guidance with this survey work. C. Bakelaar provided the maps of Hog Bay and Penetang Bay. Funding was provided to Dr. C.K. Minns by the Severn Sound Environmental Association through the Great Lakes Action Plan, Environment Canada.

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Table 1. Presence (x) or absence of fish species at electrofishing transects from Hog Bay (1990, 1995, and 2002) and Penetang Bay (1990, 2002).

Common names	Scientific names	Hog Bay	Penetang Bay
Longnose gar	*Lepisosteus osseus*	x	x
Bowfin	*Amia calva*	x	x
Alewife	*Alosa pseudoharengus*	x	x
Northern pike	*Esox lucius*	x	x
Muskellunge	*Esox masquinongy*	x	
Central mudminnow	*Umbra limi*		x
Quillback	*Carpiodes cyprinus*		x
White sucker	*Catostomus commersoni*	x	x
Silver redhorse	*Moxostoma anisurum*		x
Shorthead redhorse	*Moxostoma macrolepidotum*		x
Common carp	*Cyprinus carpio*	x	x
Golden shiner	*Notemigonus crysoleucas*	x	x
Emerald shiner	*Notemigonus atherinoides*		x
Common shiner	*Luxilus cornutus*	x	
Blackchin shiner	*Notropis heterodon*	x	x
Blacknose shiner	*Notropis heterolepis*	x	x
Spottail shiner	*Notropis hudsonius*	x	x
Bluntnose minnow	*Pimephales notatus*	x	x
Creek chub	*Semotilus atromaculatus*	x	x
Brown bullhead	*Ameiurus nebulosus*	x	x
Stonecat	*Notorus flavus*		x
Banded killifish	*Fundulus diaphanous*		x
White perch	*Morone Americana*		x
White bass	*Morone chrysops*		x
Rock bass	*Ambloplites rupestris*	x	x
Pumpkinseed	*Lepomis gibbosus*	x	x
Bluegill	*Lepomis macrochirus*	x	
Smallmouth bass	*Micropterus dolomieu*	x	x
Largemouth bass	*Micropterus salmoides*	x	x
Black crappie	*Pomoxis nigromaculatus*	x	x
Yellow perch	*Perca flavescens*	x	x
Walleye	*Stizostedium vitreum*	x	
Brook silverside	*Labidesthes sicculus*	x	x
Total number of species:		24	29

Table 2. Sampling effort in Hog Bay and Penetang Bay, Severn Sound, 1990, 1995 and 2002

Location	Year	Number of transects	Visits	Total number of samples
Hog Bay	1990	7	2	14
	1995	7	2	14
	2002	7	2	13
Penetang Bay	1990	14	2	28
	2002	14	2	28

Table 3. Individual Index of Biotic Integrity (IBI) metrics

Metric name	**Influence on IBI**
Native species richness	Positive
Centrarchid species richness	Positive
Intolerant species richness	Positive
Non-native species richness	Negative
Native cyprinid species richness	Positive
Percent piscivore biomass	Positive
Percent generalist biomass	Negative
Percent specialist biomass	Positive
Number of native individuals	Positive
Biomass of natives (kg)	Positive
Percent non-native species by number	Negative
Percent non-native species by biomass	Negative

Table 4. Mean biomass (kg) of fish by species, year and habitat type (sparse and dense macrophyte cover) captured by electrofishing in Hog Bay and Penetang Bay. The proportion of samples where species occurred is indicated in parentheses.

Species	Hog Bay			Penetang Bay			
	1990	1995	2002	1990		2002	
	Dense	Dense	Dense	Sparse	Dense	Sparse	Dense
Longnose gar			0.004 (0.08)			0.018 (0.13)	
Bowfin	0.427 (0.07)	0.248 (0.29)	0.830 (0.14)		0.204 (0.09)		0.310 (0.10)
Alewife	0.001 (0.07)		<0.001(0.01)	0.130 (0.50)	0.009 (0.14)	0.001 (0.25)	0.003 (0.35)
Northern pike	0.094 (0.07)	0.252 (0.29)	0.100 (0.01)		0.138 (0.05)		
Muskellunge			0.005 (015)				
Central mudminnow							0.001 (0.05)
Quillback				0.320 (0.33)	0.150 (0.14)		
White sucker	0.054 (0.07)	0.052 (0.14)	0.285(0.38)	0.862 (0.33)	1.552 (0.59)	0.112 (0.13)	0.145 (0.35)
Silver redhorse						0.338 (0.13)	0.104 (0.05)
Shorthead redhorse					0.061 (0.09)		
Minnow sp.			0.001 (0.14)			0.002 (0.13)	0.001 (0.30)[1]
Common carp	0.903 (0.21)	3.493 (0.21)	1.305 (0.38)		1.391 (0.23)		0.175 (0.05)
Golden shiner	0.009 (0.21)	0.007 (0.29)	0.002 (0.38)		0.003 (0.14)		
Emerald shiner					0.001 (0.05)		0.001 (0.20)
Common shiner		0.002 (0.21)					
Blackchin shiner	0.003 (0.43)	0.007 (0.71)			0.002 (0.27)		
Blacknose shiner			0.002 (0.38)				0.001 (0.35)
Spottail shiner		0.001 (0.21)	0.001 (0.08)	0.001 (0.17)		0.001 (0.25)	0.003 (0.35)
Bluntnose minnow	0.001 (0.14)	0.001 (0.07)		0.001 (0.33)	0.001 (0.27)	0.002 (0.38)	0.001 (0.35)
Creek chub			0.002 (0.31)			0.002 (0.13)	0.001 (0.10)
Brown bullhead	0.061 (0.14)	0.094 (0.21)	0.222 (0.38)		0.119 (0.05)		0.076 (0.30)
Stonecat							0.001 (0.10)
Banded killifish						0.001 (0.13)	0.001 (0.05)
White perch						0.056 (0.25)	
White bass					0.022 (0.32)		
Rock bass	0.077 (0.43)	0.056 (0.50)	0.013 (0.23)	0.058 (0.33)	0.095 (0.41)	0.022 (0.25)	0.046 (0.35)
Pumpkinseed	1.163 (1.00)	0.686 (1.00)	0.156 (1.00)	0.162 (0.67)	0.517 (0.86)	0.107 (0.63)	0.573 (1.00)
Blugegill			0.008 (0.08)				
Smallmouth bass	0.092 (0.07)	0.033 (0.07)		0.456 (0.67)	0.095 (0.23)	0.020 (0.25)	0.001 (0.10)
Largemouth bass	0.942 (0.93)	0.913 (0.86)	0.751 (1.00)		0.288 (0.55)	0.147 (0.75)	0.498 (1.00)
Black crappie	0.077 (0.64)	0.018 (0.57)	0.017 (0.46)	0.045 (0.17)	0.046 (0.36)	0.004 (0.17)	0.003 (0.10)
Yellow perch	1.075 (1.00)	0.151 (0.86)	0.224 (1.00)	0.289 (0.67)	1.374 (0.95)	0.024 (0.25)	0.063 (0.45)
Walleye	0.084 (0.07)						
Brook silverside	0.001 (0.21)	<0.001 (0.07)	<0.001 (0.15)		<0.001 (0.09)		<0.001 (0.20)
No. of transects:	7	7	7	3	11	4	10
No. of samples[2]:	14	14	13	6	22	8	20
Total[3] (kg):	70.9	84.2	51.1	13.9	133.4	6.8	40.1

[1] weights for 2 fish not included in the calculation of biomass

[2] each transect was usually visited twice a year

[3] total weight (kg) of all species caught for that bay and year

Table 5. Mean numbers of fish by species, year and habitat type (sparse or dense macrophyte cover) captured by electrofishing in Hog Bay and Penetang Bay.

Species	Hog Bay			Penetang Bay			
	1990	1995	2002	1990		2002	
	Dense	Dense	Dense	Sparse	Dense	Sparse	Dense
Longnose gar			0.1			0.1	
Bowfin	0.2	0.3	0.4		0.1		0.1
Alewife	0.4		0.1	4.2	4.8	0.6	1.1
Northern pike	0.1	0.3	0.1		0.1		
Muskellunge			0.2				
Central mudminnow							0.1
Quillback				0.3	0.1		
White sucker	0.1	0.1	0.5	1.2	1.9	0.1	0.6
Silver redhorse						0.1	0.1
Shorthead redhorse					0.1		
Minnow sp.			0.3			0.5	2.2
Common carp	0.3	0.9	0.6		0.4		0.1
Golden shiner	0.5	0.9	0.5		0.2		
Emerald shiner					0.1		0.2
Common shiner		0.2					
Blackchin shiner	1.9	3.4			0.6		
Blacknose shiner			1.2				0.9
Spottail shiner		0.4	0.2	0.2		0.4	0.6
Bluntnose minnow	0.4	0.1		0.3	0.4	1.0	0.7
Creek chub			0.5			0.3	0.7
Brown bullhead	0.2	0.4	0.8		0.5		0.4
Stonecat							0.1
Banded killifish						0.1	0.1
White perch						0.6	
White bass							
Rock bass	1.1	0.9	0.2	0.7	1.7	0.3	1.0
Pumpkinseed	28.4	15.7	5.8	1.5	10.0	3.3	20.4
Bluegill			0.1				
Smallmouth bass	0.1	0.1		2.7	0.4	0.3	0.1
Largemouth bass	4.6	3.7	6.5		1.3	4.6	9.8
Black crappie	1.5	1.3	0.5	0.3	0.5	0.1	0.1
Yellow perch	22.4	10.8	11.4	5.8	22.5	0.3	0.9
Walleye	0.1						
Brook silverside	0.4	0.1	0.2		0.1		0.3
No. of transects	7	7	7	3	11	4	10
No. of samples[1]:	14	14	13	6	22	8	20
Total[2]:	873	554	391	103	1010	101	802

[1] each transect was usually visited twice a year

[2] total numbers of all species caught for that bay and year

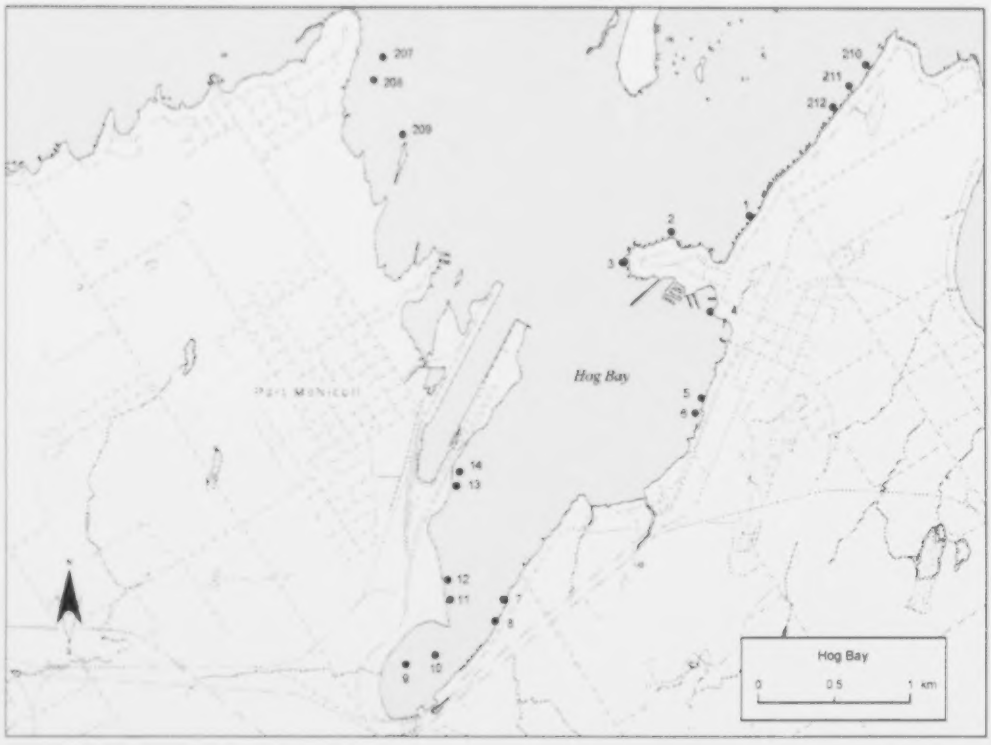

Figure 1: Map of Hog Bay

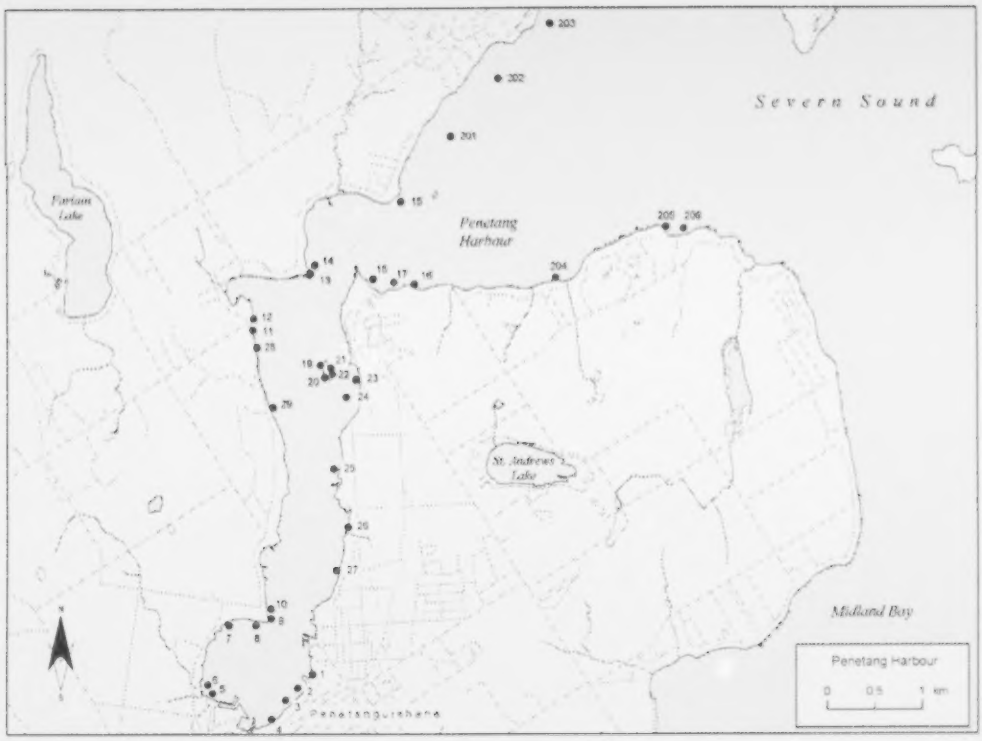

Figure 2: Map of Penetang Bay

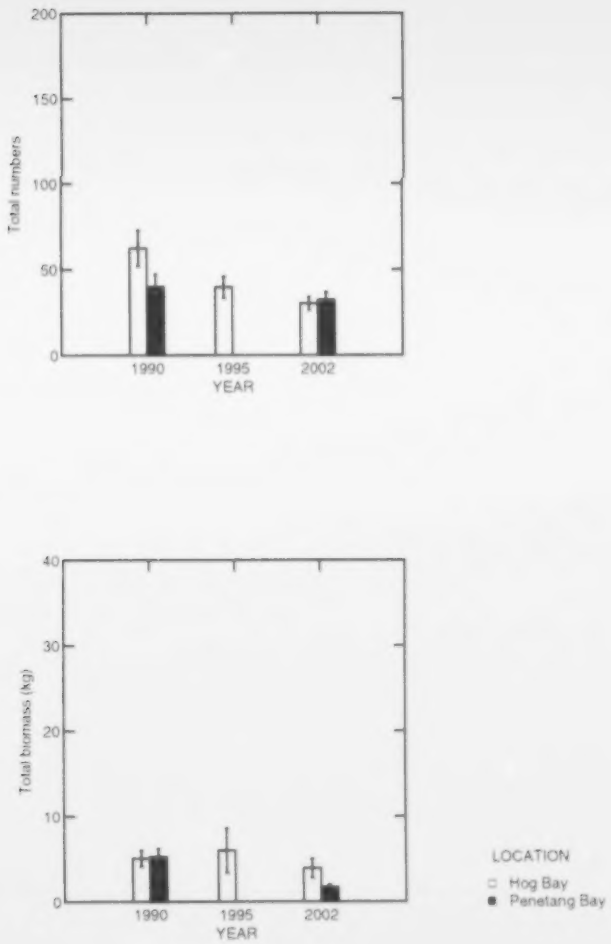

Figure 3: Average number (upper) and biomass (lower) of fish captured in Hog Bay (1990,1995 and 2002) and Penetang Bay (1990, 2002) (annual mean ± SE).

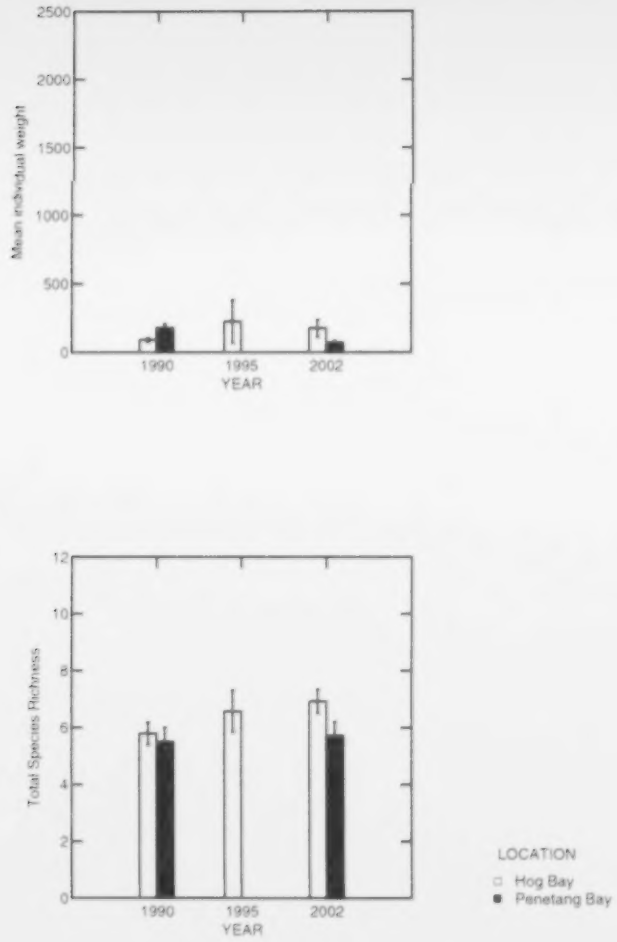

Figure 4: Mean individual weights (g) (upper) and average total species richness (lower) in Hog Bay (1990, 1995, and 2002) and Penetang Bay (1990, 2002) (annual mean ± SE).

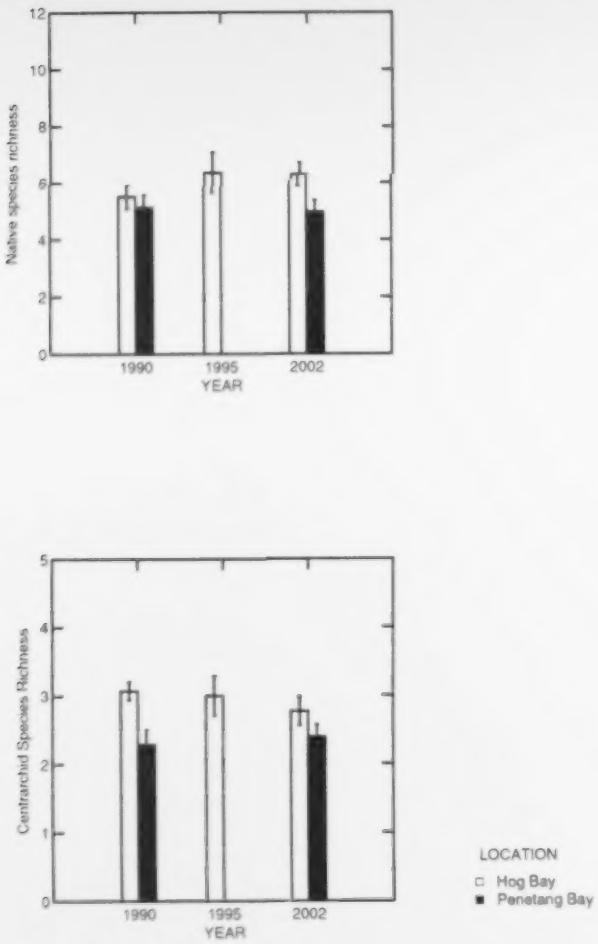

Figure 5: Average native species richness (upper) and average centrarchid species richness (lower) in Hog Bay (1990, 1995, and 2002) and Penetang Bay (1990, 2002) (annual mean ± SE).

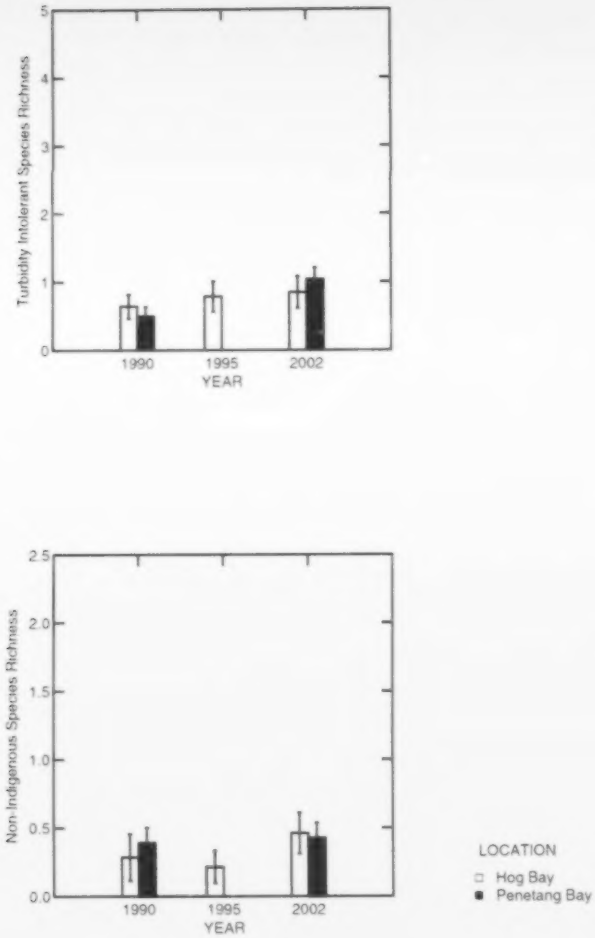

Figure 6: Average turbidity intolerant species richness (upper) and average non-native species richness (lower) in Hog Bay (1990, 1995, and 2002) and Penetang Bay (1990, 2002) (annual mean ± SE).

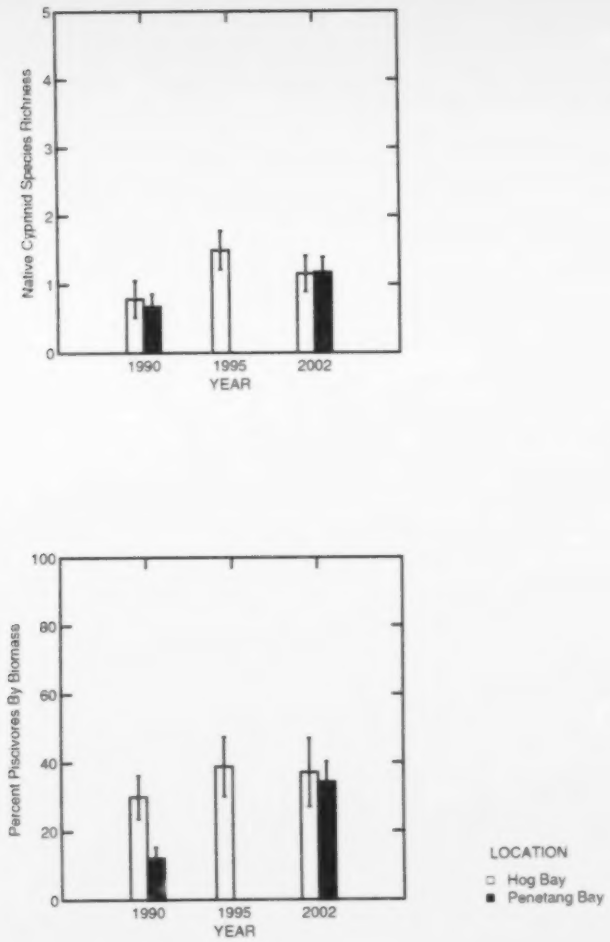

Figure 7: Average native cyprinid species richness (upper) and mean percent piscivores by biomass (lower) in Hog Bay (1990, 1995, and 2002) and Penetang Bay (1990, 2002) (annual mean ± SE).

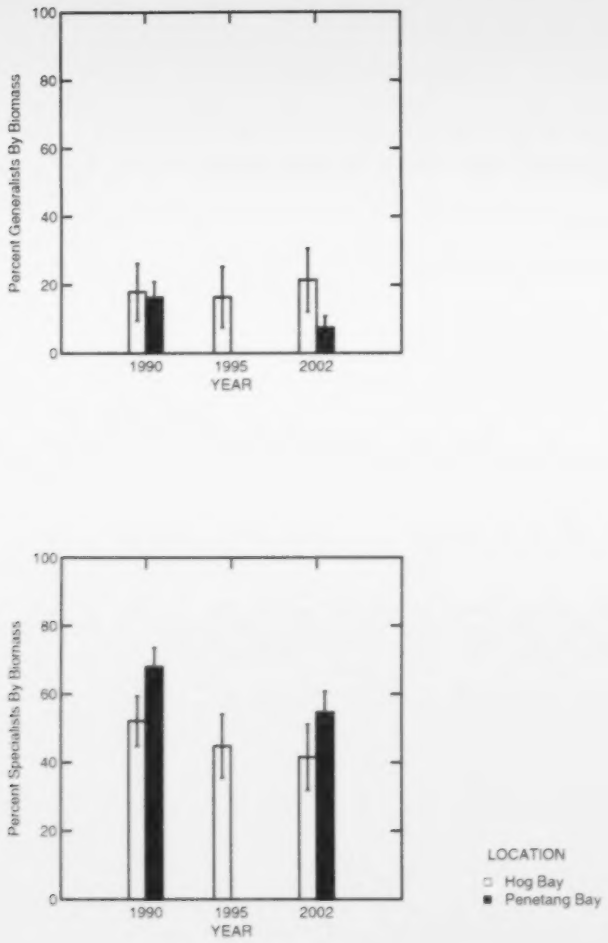

Figure 8: Mean percent generalists by biomass (upper) and mean percent specialists by biomass (lower) in Hog Bay (1990, 1995, and 2002) and Penetang Bay (1990, 2002) (annual mean ± SE).

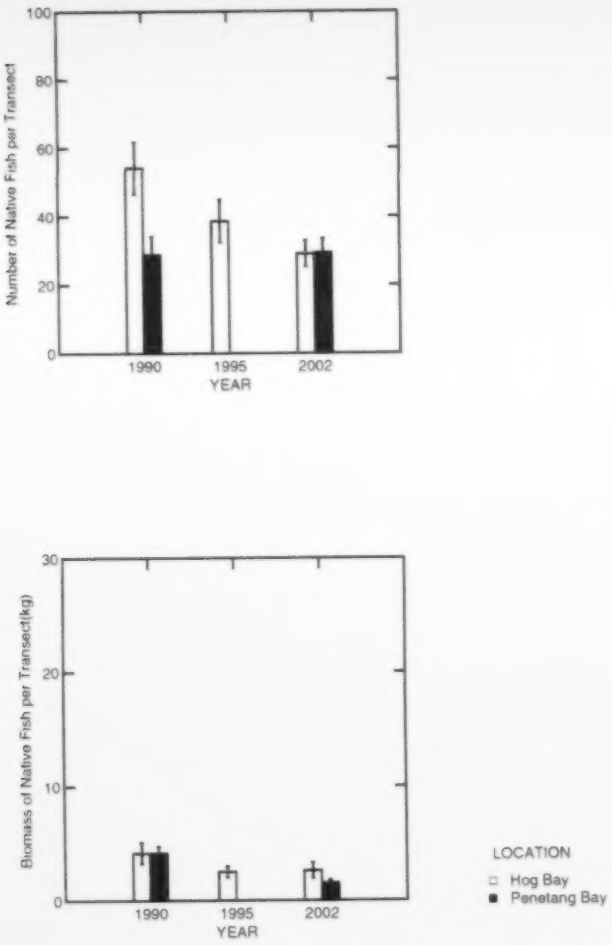

Figure 9: Average number of native fish (upper) and average biomass of native fish (lower) in Hog Bay (1990, 1995, and 2002) and Penetang Bay (1990, 2002) (annual mean ± SE)

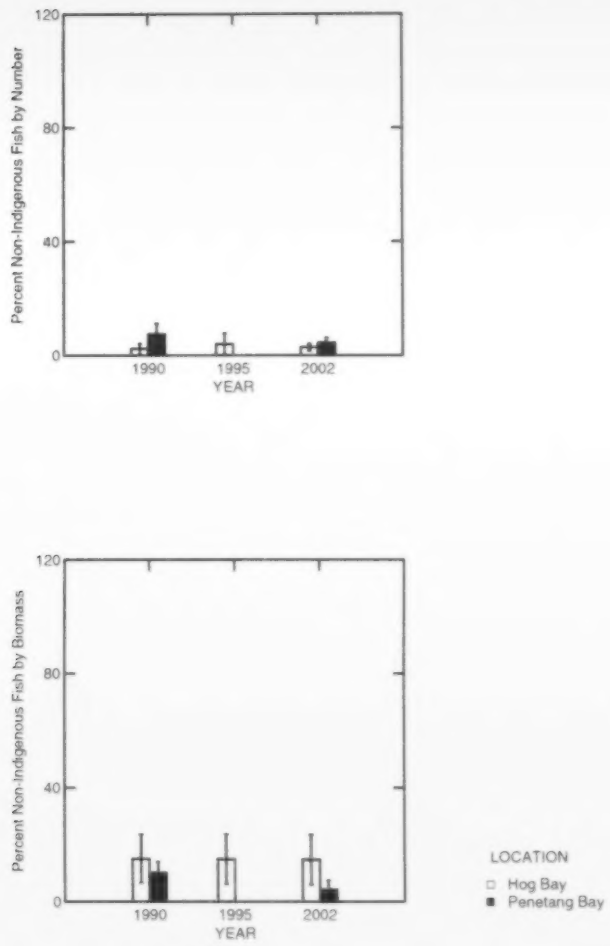

Figure 10: Mean percent non-native fish by number (upper) and mean percent non-native fish by biomass (lower) in Hog Bay (1990, 1995, and 2002) and Penetang Bay (1990, 2002) (annual mean ± SE).

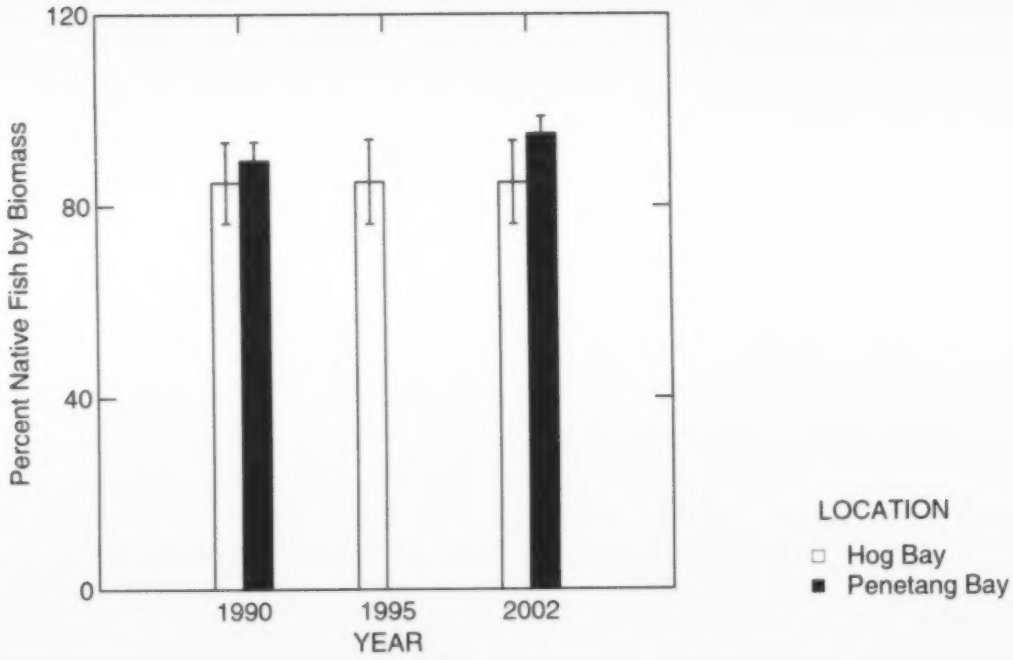

Figure 11: Percent native fish by biomass in Hog Bay (1990, 1995, and 2002) and Penetang Bay (1990, 2002) (annual mean ± SE).

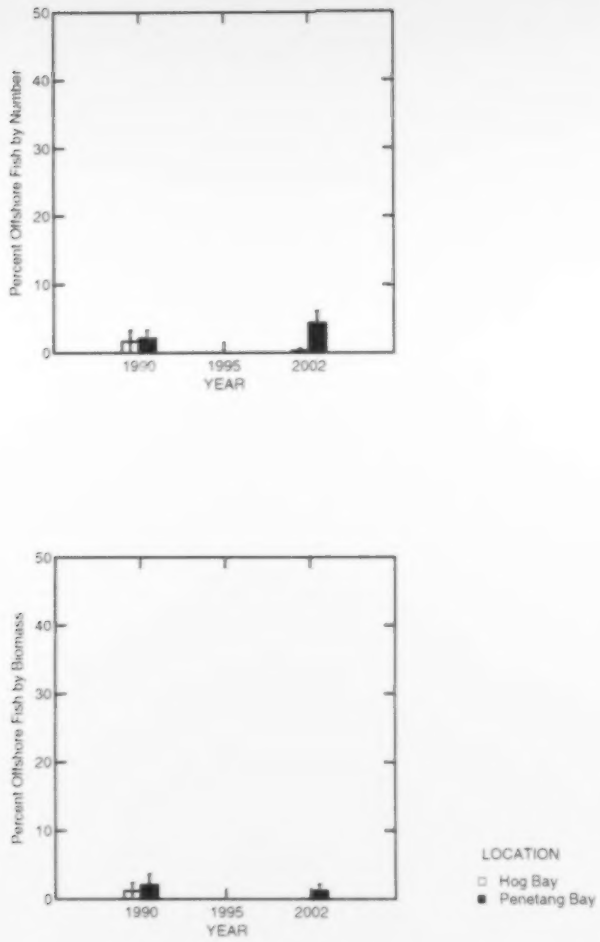

Figure 12: Mean percent offshore fish by number (upper) and mean percent offshore fish by biomass (lower) in Hog Bay (1990, 1995, and 2002) and Penetang Bay (1990, 2002) (annual mean ± SE).

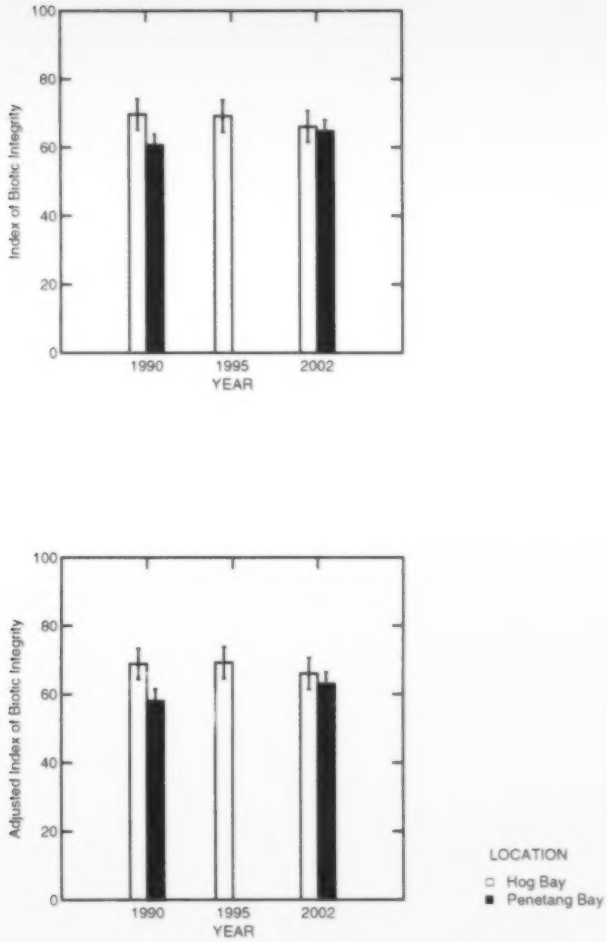

Figure 13: Average Index of Biotic Integrity (IBI) scores (upper) and average Adjusted Index of Biotic Integrity (IBI*) scores (lower) in Hog Bay (1990, 1995, and 2002) and Penetang Bay (1990, 2002) (annual mean ± SE).

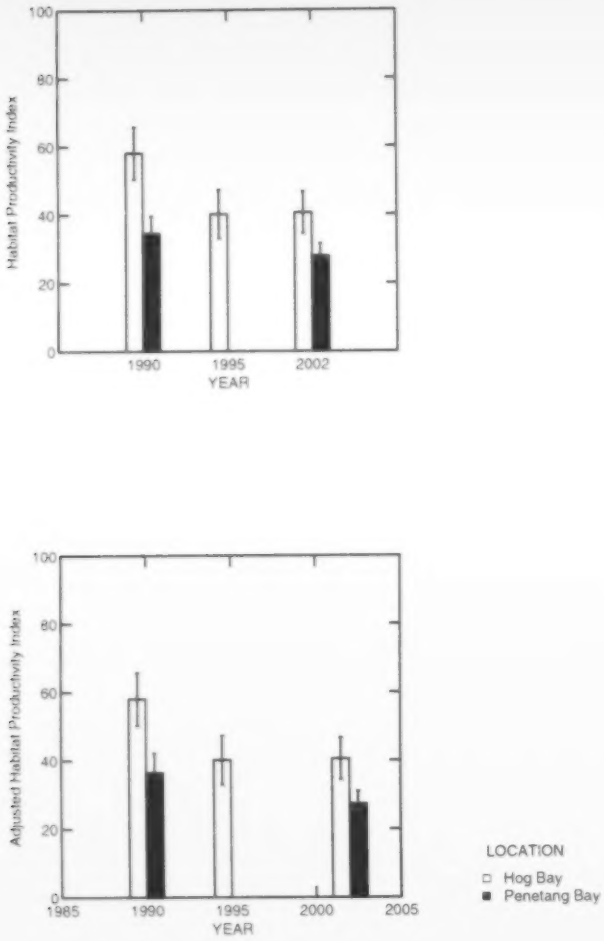

Figure 14: Average Habitat Productivity Index (HPI) scores (upper) and average Adjusted Habitat Productivity Index (HPI*) scores (lower) in Hog Bay (1990, 1995, and 2002) and Penetang Bay (1990, 2002) (annual mean ± SE).

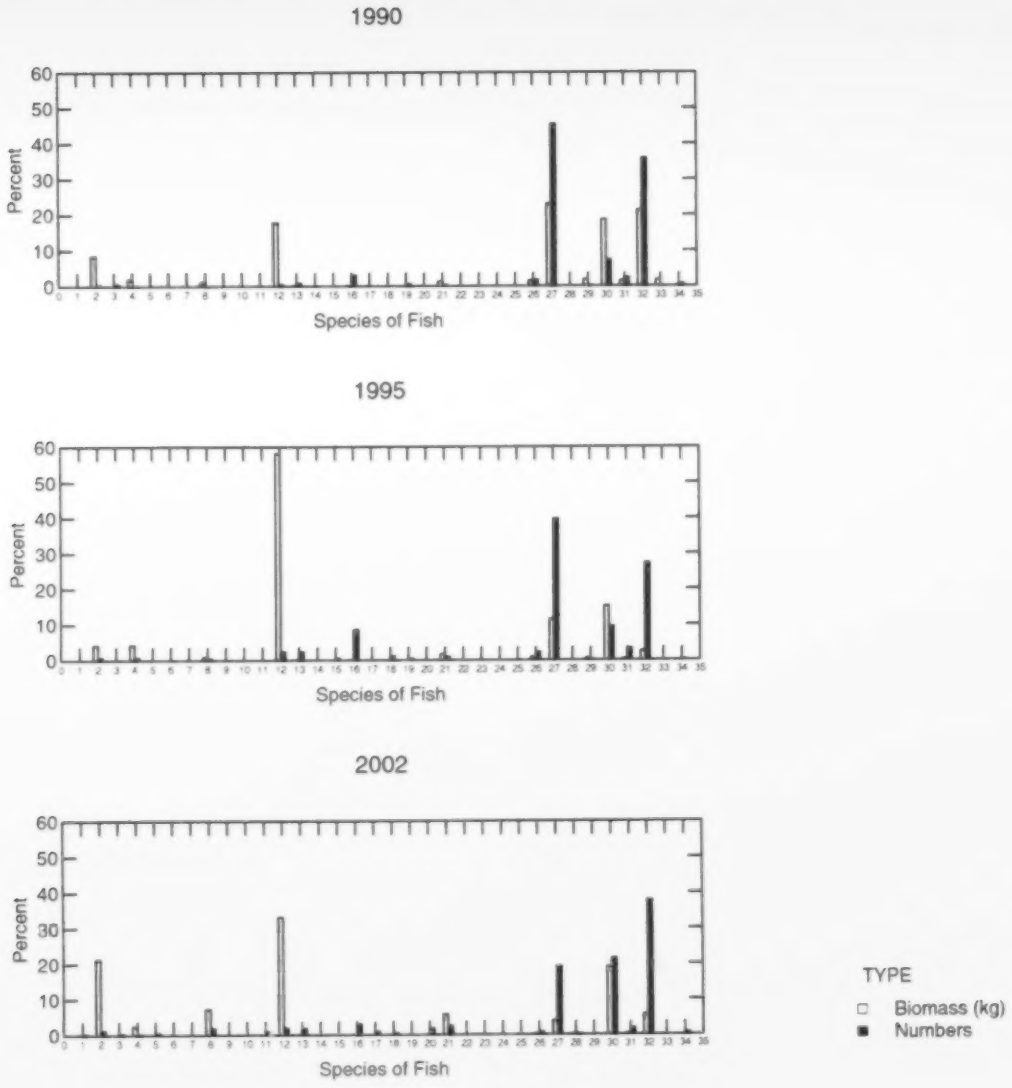

Figure 15: Histograms of percent biomass and numbers by species and year in moderate to heavily vegetated areas in Hog Bay. The species of fish are: 1-longnose gar, 2-bowfin, 3-alewife, 4-northern pike, 5-muskellunge, 6-central mudminnow, 7-quillback, 8-white sucker, 9-silver redhorse, 10-shorthead redhorse, 11-minnow sp., 12-common carp, 13-golden shiner, 14-emerald shiner, 15-common shiner, 16-blackchin shiner, 17- blacknose shiner, 18-spottail shiner, 19-bluntnose minnow, 20-creek chub, 21-brown bullhead, 22-stonecat, 23-banded killifish, 24-white perch, 25-white bass, 26-rock bass, 27-pumpkinseed, 28-bluegill, 29-smallmouth bass, 30-largemouth bass, 31-black crappie, 32-yellow perch, 33-walleye, and 34-brook silverside.

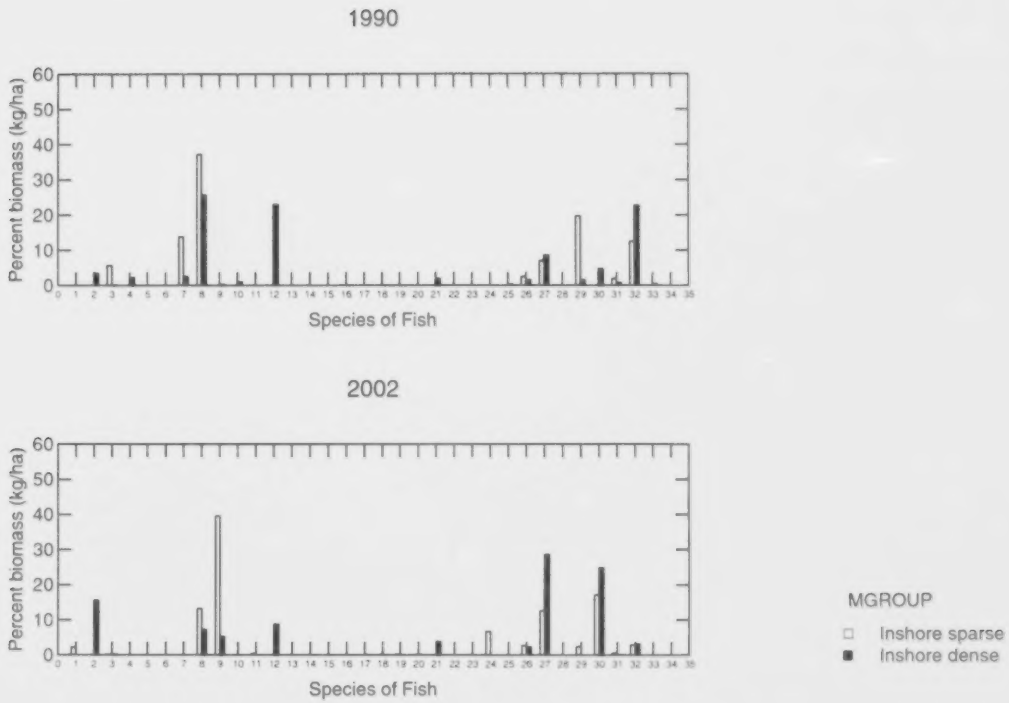

Figure 16: Histograms of percent biomass by species, area (inshore dense vegetation and inshore sparse vegetation), and year in Penetang Bay. The species of fish are: 1-longnose gar, 2-bowfin, 3-alewife, 4-northern pike, 5-muskellunge, 6-central mudminnow, 7-quillback, 8-white sucker, 9-silver redhorse, 10-shorthead redhorse, 11-minnow sp., 12-common carp, 13-golden shiner, 14-emerald shiner, 15-common shiner, 16-blackchin shiner, 17- blacknose shiner, 18-spottail shiner, 19-bluntnose minnow, 20-creek chub, 21-brown bullhead, 22-stonecat, 23-banded killifish, 24-white perch, 25-white bass, 26-rock bass, 27-pumpkinseed, 28-bluegill, 29-smallmouth bass, 30-largemouth bass, 31-black crappie, 32-yellow perch, 33-walleye, and 34-brook silverside.

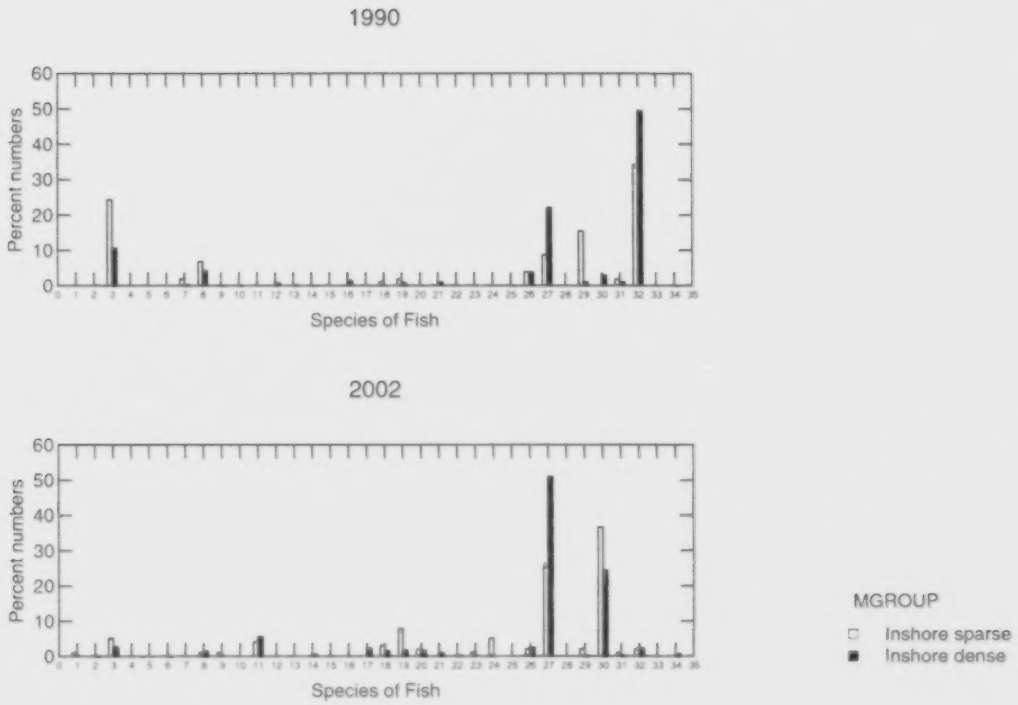

Figure 17.: Histograms of percent numbers by species, area (inshore dense vegetation and inshore sparse vegetation), and year in Penetang Bay. The species of fish are: 1-longnose gar, 2-bowfin, 3-alewife, 4-northern pike, 5-muskellunge, 6-central mudminnow, 7-quillback, 8-white sucker, 9-silver redhorse, 10-shorthead redhorse, 11-minnow sp., 12-common carp, 13-golden shiner, 14-emerald shiner, 15-common shiner, 16-blackchin shiner, 17- blacknose shiner, 18-spottail shiner, 19-bluntnose minnow, 20-creek chub, 21-brown bullhead, 22-stonecat, 23-banded killifish, 24-white perch, 25-white bass, 26-rock bass, 27-pumpkinseed, 28-bluegill, 29-smallmouth bass, 30-largemouth bass, 31-black crappie, 32-yellow perch, 33-walleye, and 34-brook silverside.